

ADVANCED SYMBOLOGY FOR GENERAL AVIATION APPROACH
TO LANDING DISPLAYS

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ABSTRACT

This presentation describes a set of flight tests designed to evaluate the relative utility of candidate displays with advanced symbology for general aviation terminal area IFR operations. The symbology was previously evaluated as part of the NASA Langley Research Center's Terminal Configured Vehicle Program for use in commercial airlines. The advanced symbology included vehicle track angle, flight path angle and a perspective representation of the runway. These symbols were selectively drawn on a CRT display along with the roll attitude, pitch attitude, localizer deviation and glideslope deviation. In addition to the CRT display, the instrument panel contained standard turn and bank, altimeter, rate of climb, airspeed, heading, and engine instruments. The symbology was evaluated using tracking performance and pilot subjective ratings for an ILS capture and tracking task.

OUTLINE

The sponsoring program for the display symbology work discussed here was the GATOR program which was outlined in the presentation, "Flight Test Validation of a Design Procedure for Digital Autopilots". The current presentation includes a short background stating the purpose of this work and how the experiment was designed. The three display options evaluated are then presented, and the tracking performances for two test subjects are given. The presentation ends with some conclusions and the status of this work.

O U T L I N E

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- Background and Experiment Design
- Display Options
- Tracking Performance
- Conclusions and Status

EXPERIMENT PURPOSE AND DESIGN

The advantages of CRT displays in the cockpit have been demonstrated for the commercial airline class vehicle through such programs as NASA Langley's Terminal Configured Vehicle (TCV) program (Ref. 1). Further, the incorporation of electronic displays in the Boeing 757 and 767 is indicative of display hardware technology maturity. It is not clear how this technology can be best applied to general aviation aircraft with their more limited panel space and display system budget, and which are used by pilots with a broad skill range. For these reasons, the current study was initiated with the main objective of determining the relative merit of various symbology levels in the GA IFR approach to landing environment.

The display concepts are based on TCV developed formats and include the ability to selectively draw a perspective representation of the runway, a measure of the current flight path angle, and presentation of a relative ground track angle. The tests were conducted in a GA aircraft (Princeton's Navion) using the NASA LaRC DARE package described in the companion autopilot presentation. The original intent was to use GA pilots, but actually two GA pilots and two NASA test pilots participated in the study. Two measures of symbology value were used: (1) a statistical analysis of localizer and glideslope tracking performance, and (2) pilot ratings and comments.

ADVANCE DISPLAY SYMBOLOGY RESEARCH

OBJECTIVE: DETERMINE THE VALUE OF ADVANCED SYMBOLOGY FOR GA IFR APPROACH AND LANDING

DISPLAY CONCEPTS

- MODIFIED COMMERCIAL AIRCRAFT SYMBOLOGY
 - PERSPECTIVE RUNWAY
 - FLIGHT PATH ANGLE
 - RELATIVE GROUND TRACK ANGLE

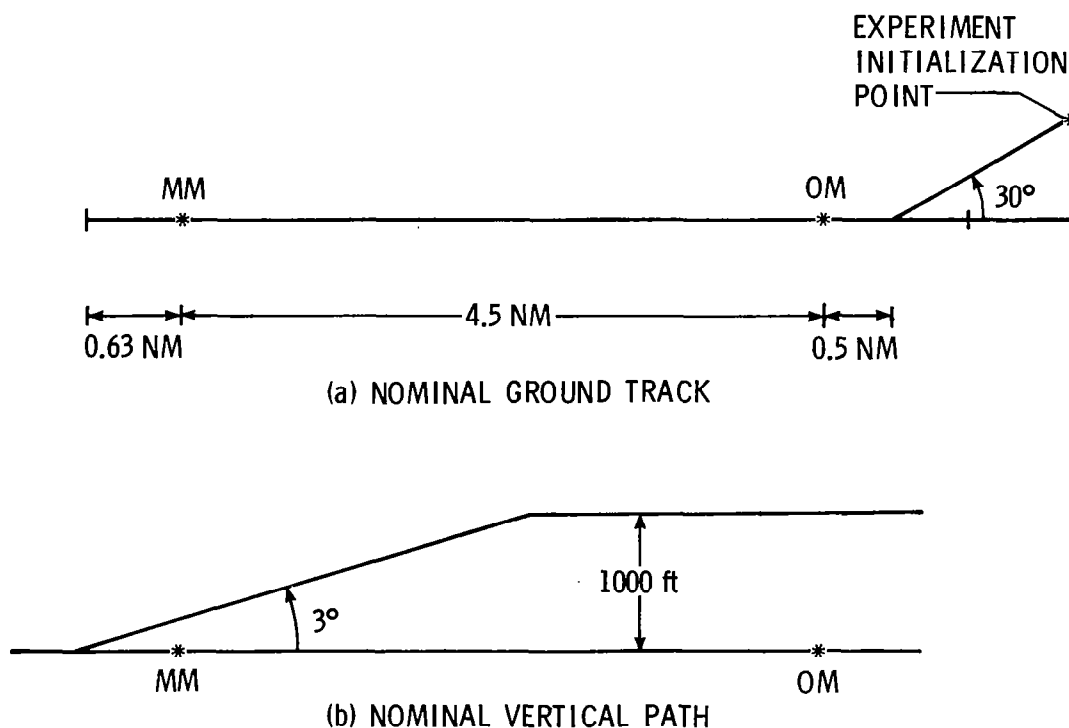
EXPERIMENT DESIGNS

- FLIGHT TEST USING GA PILOTS IN GA AIRCRAFT
- STATISTICAL ANALYSIS OF TRACKING PERFORMANCE
- SUBJECTIVE PILOT RATING

TEST RUN DESCRIPTION

The task required the interception and tracking of an ILS localizer and glideslope as shown in the figure. The safety pilot positioned the aircraft at the initialization point at approximately 1000 feet and 80 knots with the wheels down and the flaps up. The subject pilot was then given control of the aircraft and proceeded to "fly an 80 knot approach, tracking the localizer and glideslope as tightly as possible." The run ended at the CAT-1 ILS decision height of 200 feet. A data run from initialization to initialization required about 15 minutes; six approaches for a single display option could be completed in a 1-1/2 hour flight. Two approaches were used for training, and the remaining four were used for analysis. While the aircraft was returning to the initialization point, the pilot would relay subjective ratings and comments to ground observers.

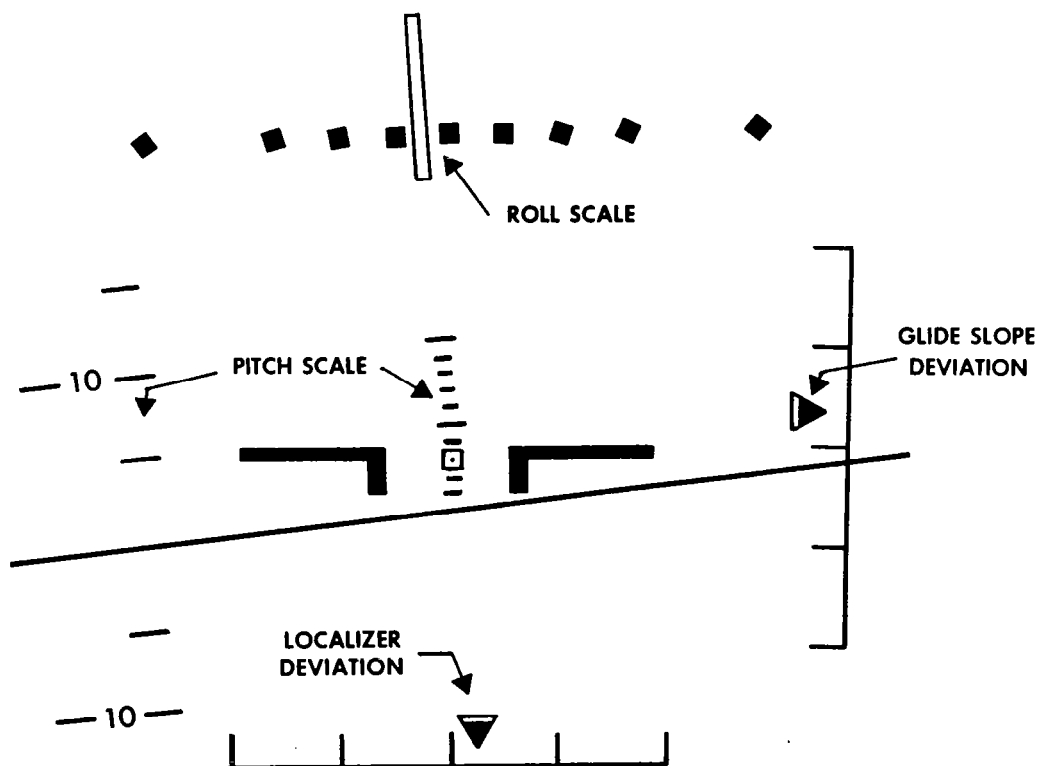
NOMINAL FLIGHT PATH



BASELINE DISPLAY

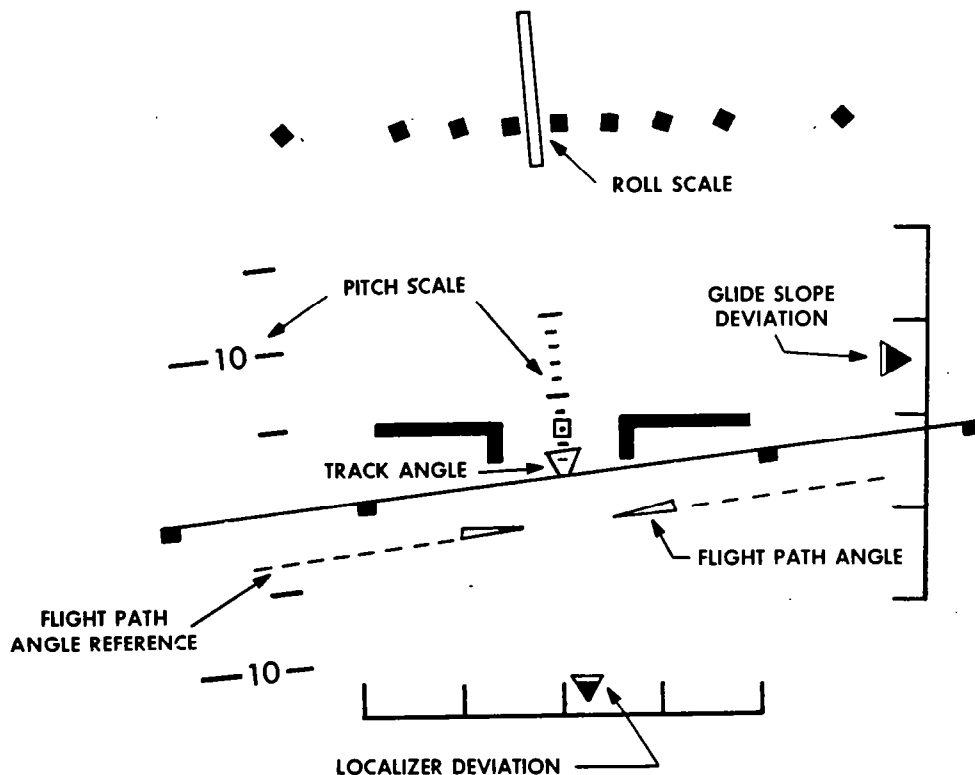
The baseline display shown here presented the information normally found on an attitude deviation indicator (an aircraft symbol, a horizon line, a pitch scale, and a roll scale). Added to this were localizer and glideslope deviations. The aircraft symbol was fixed relative to the CRT frame but could be adjusted up or down by the pilot in a manner similar to that found on an artificial horizon. The roll scale had marks at 15 degree intervals over a range of ± 45 degrees. The pitch scale at the left shows a 25 degree range with numerical labels at 10 degree increments; the scale at the center has marks at $+5$ degree and $+10$ degree pitch attitude. The square in the center of the A/C symbol was programmed to blink at outer and middle marker passage.

The raw ILS deviations were displayed on linear scales with marks at 0, $\pm 50\%$, and $\pm 100\%$. Full scale readings corresponded to 2.5 degrees on localizer and 0.7 degrees for glideslope. None of the symbols was damped or smoothed.



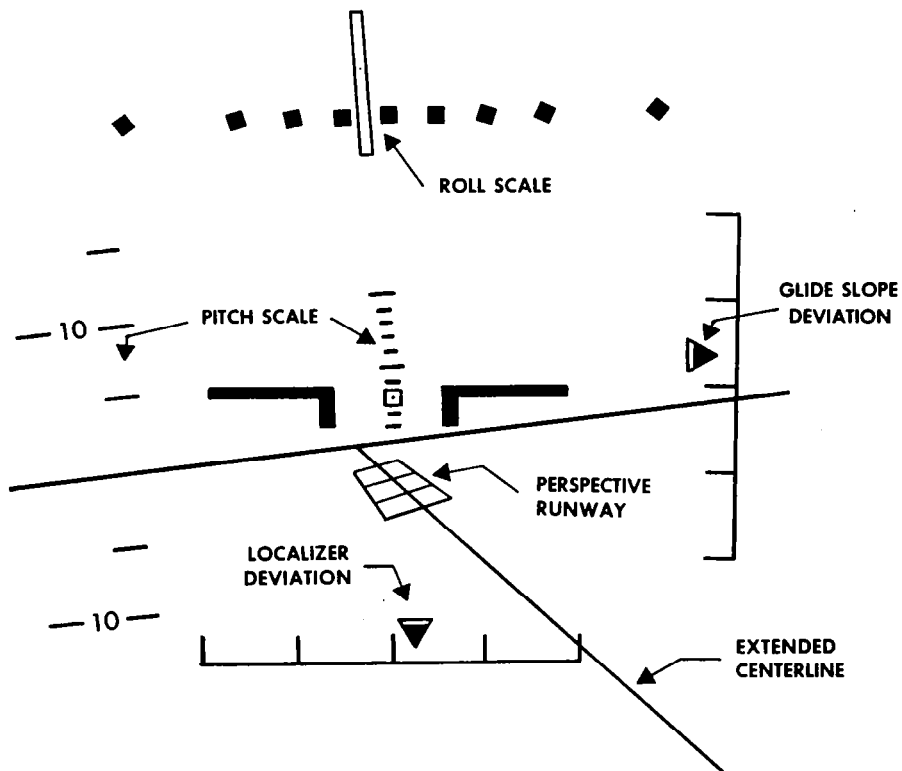
ADVANCED DISPLAY OPTION 1

Advanced Display Option 1 added to the baseline display two additional pieces of data: (1) a ground-referenced track angle, and (2) a ground-referenced flight path angle. A dashed line parallel to the horizon was added to represent the 3 degree nominal glideslope angle. The track angle is defined as the angle between the aircraft's ground-speed in the horizontal plane and the runway centerline, and is useful for localizer intercept and capture since it provides a measure of the localizer closure rate and includes the effect of wind. During localizer tracking, it gives a measure of departure rate due to crosswinds or changing wind conditions. The pilot has only to adjust the aircraft heading so that the track angle is zero to fly a ground track parallel to the runway centerline. If the localizer deviation is also zero, the pilot is flying a ground track directly on the localizer. This additional information can potentially reduce the workload associated with the iterative process of finding the crab angle which compensates for crosswinds.



ADVANCED DISPLAY OPTION 2

Advanced Display Option 2 augments the baseline display with a perspective image of the runway having an extended centerline. The runway image was formed by displacing it according to the vehicle's position and rotating it through the vehicle's pitch and roll angles and the ground track angle. The use of track angle rather than the more conventional heading was done for two reasons: (1) it made the runway and centerline image move more gradually, and (2) its use made the relative orientation of the runway provide a measure of the aircraft's track angle.



PILOTING EXPERIENCE OF SUBJECTS

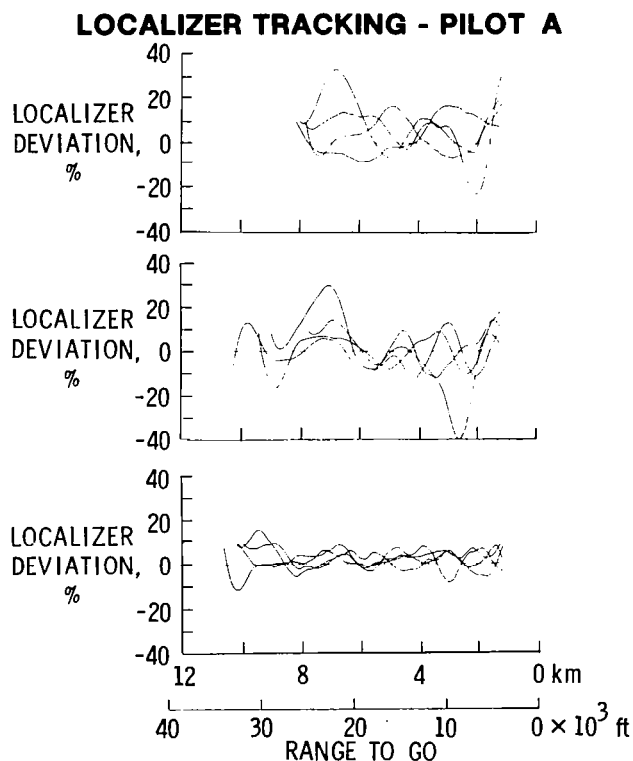
Data for two test subjects are presented here; Pilot A was a test pilot, and Pilot B was a GA pilot with an instrument rating.

SUBJECT PILOTS EXPERIENCE

	TOTAL HOURS	INSTRUMENT HOURS	RATINGS
PILOT A	7000	1000	ATP, CFI
PILOT B	526	60	PVT, INSTRUMENT RATING

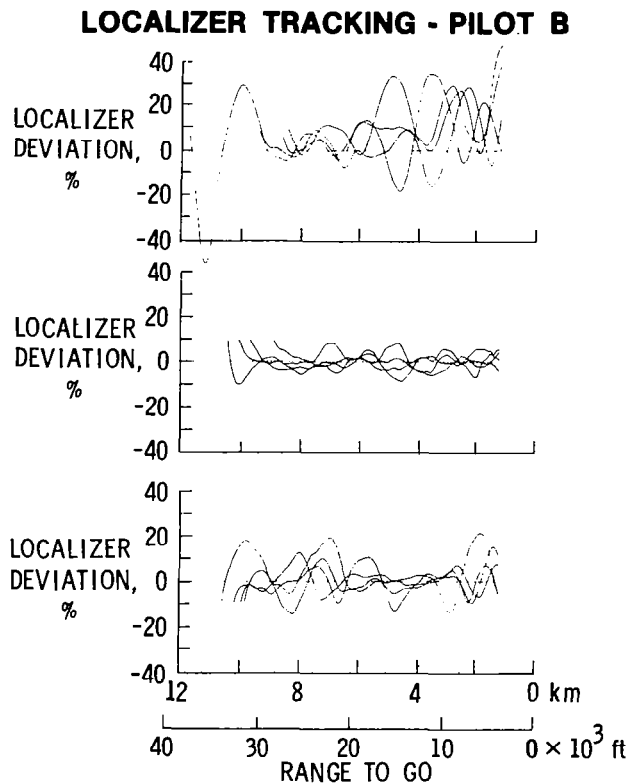
TRACKING PERFORMANCE DATA--TEST PILOT

Shown here is the localizer tracking performance for the test pilot for each of the three displays. The top plots represent the deviation in percent recorded during the four data runs for the baseline display; the center plots, Option 1; and the lower plots, Option 2. It can be seen from this data that the use of the Option 2 display resulted in a substantial improvement in localizer tracking for this subject, while there was essentially no improvement over the baseline with the use of Option 1. The next figure shows an interesting observation for the GA pilot.



TRACKING PERFORMANCE DATA--GA PILOT

The localizer tracking histories for the GA pilot data runs are given here, with the top, baseline; center, Option 1; and lower, Option 2. It can be seen that both Options 1 and 2 gave better tracking performance than the Baseline, with Option 2 clearly the better. This is not the same result noted with the test pilot in the previous chart. With the limited data developed to date, it is not clear whether this was a consequence of pilot experience, or simply pilot preference.



CONCLUSIONS & RECOMMENDATIONS

Based on data obtained from this experiment, it appears that the advanced symbology permits a more precise localizer and glideslope capture and tracking than does the baseline display. Because of the limited data developed so far, it is not possible to determine which symbology is "best." Pilot skill level and/or personal preference may be a factor. The pilot comments indicate, however, that even the baseline display is superior to conventional ADI and CDI presentations on separate instruments.

Also based largely on pilot comments, the recommendations below were derived.

C O N C L U S I O N S

- Advanced symbology permits more precise capture and tracking than does baseline.
- Data obtained thus far is inadequate to determine which advanced symbology is "best." Pilot skill level and/or personal preference may be a factor.
- Pilot comments indicate even baseline display is superior to conventional ADI and CDI presentations on separate instruments.

R E C O M M E N D A T I O N S

- Future experiments should:
 - use a side task to simulate an operational environment
 - use a "standard" electromechanical ADI and CDI as the baseline
 - evaluate new display options that combine symbology from the two advanced options
- More work is required to improve the sensitivity of the subjective rating scales.

EXPERIMENT STATUS

A total of four pilots (two GA, and two test pilots) have evaluated each of three display options. A presentation of preliminary results has been made at the AIAA Aircraft Systems and Technology Meeting in Dayton, OH, in August, 1981 (Ref. 2). This report included the data from only two of the test subjects, and the report will be revised to include the contributions of the remaining two pilots. After this revision, there is currently no future NASA work envisioned for this area.

S T A T U S

- Four pilots (2 GA, 2 Test) have evaluated each of the three displays.
- Preliminary results have been reported in at the AIAA Aircraft Systems and Technology Meeting in Dayton, OH in August, 1981.
- Preliminary report will be revised.
- No future NASA effort for this work is currently envisioned.

REFERENCES

1. Morello, S. A.: "Recent Flight Test Results Using an Electronic Display Format on the NASA B-737". Proceedings of AGARD 25th GCP Symposium on Guidance and Control Design Considerations for Low Altitude and Terminal Area Flight, Dayton, OH, October, 1977.
2. Downing, D. R.; Bryant, W. H.; and Yenni, K. R.: "Flight Test Evaluation of Advanced Symbology for General Aviation Approach to Landing Displays." Presented at the AIAA Aircraft Systems and Technology Meeting, Dayton, Ohio, August, 1981. Paper 81-1643.